A Study of the Confirming Method on 20H Rule in High Speed PCB Design

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Abstract— As the operating frequency goes higher, the PCB designers have to overcome the ever-increasing EMI (electromagnetic interference) problems. 20H rule is a unproved experiential method used by the PCB designers which can reduce EMI in PCB design. In this paper, a practice measuring method is presented based on the analyses of the reflective coefficient theory and FDTD. With this method, the 20H rule can be confirmed and commonly implemented.

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1. INTRODUCTION

The 20H rule was first presented by W. Michael King. In 1980, the 20H rule was recognized and used to reduce EMI. In 1996, the rule was embodied in a book [1] by Mr. Mark I Montrose. The 20H rule is about the relation of the power plane and the ground plane, but is only a still unproved rule established by usage. The different application of the 20H rule results different effects in PCB designing works, as it may reduce EMI or may increase EMI in different circumstances. So Confirming the 20H rule and studying its application circumstances has a practice importance.

2. 20H RULE

20H rule: If there are high-speed currents on the board, there are electromagnetic fields associated with them. At the edge of the planes (presumably at the edge of the board) these fields will fringe outward from the board as shown in Figure 1. If the ground plane is larger than the power plane, the energy can not radiate out, as we can see from Figure 1(b). Thus, outward EMI radiation is reduced and there is less chance for an external EMI problem.

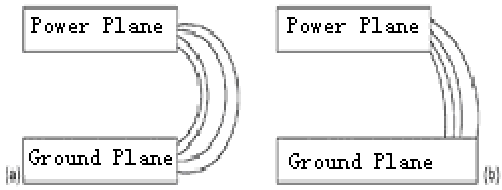

Figure 1: Recessing power plane may reduce outward fringing.

The reduction of edge radiation relates to the plane edge retraction. 20H role (H is the height between the power plane and the ground plane) take it that if the power plane edge is retracted 20H of the ground plane edge, 70% of the energy radiation can be repressed.

20H rule is experiential method without theoretically confirmation and demonstration. Some designers believe that the 20H rule will cause more radiation than not applying it [2, 3]. There also exist a saying that whether the 20H role is applicable depends on the dimension of the PCB and the frequency and the layers separation [4]. Others think that using discrete components instead of implementing the 20-H rule is another choice [5].

3. CONFIRMING METHOD

There is no such a method which can be used to accurately analyze 20H rule. In general, reflective coefficient, FDTD and antenna theories are used to simple analyze 20H rule.

The method of radiating coefficient is a way that analyzes the radiation through the PCB edge's reflective coefficient. FDTD has the advantage of analyzing the electromagnetic phenomenon, so it can be used to emulate the various conditions such as PCB with different dimension, or with different layer separation; different frequency; nH etc. using FDTD we can compare the result between the one using 20H rule and not using it that would give us more information about the 20H rule's application.

3.1. The Method of Reflective Coefficient

Building two 2-layers models (One use 20H rule, and another is normal). It can be seen in Figure 2.

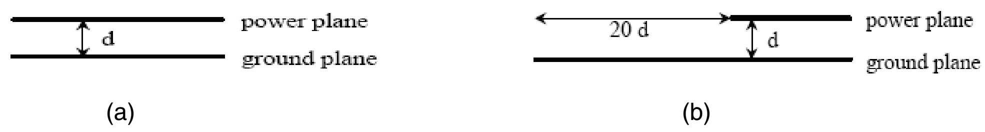

Figure 2: A model consist of two layers. (a) Two planes are of the same size, (b) 20H rule.

The radiation firmly relate to the reflection coefficient of the two layers' edge.

Take the plane thickness as 0, the edge reflection coefficient of the two planes [6]

$$R = |R|e^{-j\theta} \tag{1}$$

Amplitude

$$|R| = e^{-\pi q} \tag{2}$$

Phase:

$$\theta = 2q\left[1 - C + \ln\frac{2}{q} - \left(\frac{\sin^{-1} q}{q} - 1\right) - \sum_{m=1}^{x} A_{2m+1}\left(S_{2m+1} - 1\right) q^{2m}\right] \tag{3}$$

As the charge $q = CU$, C is the function of the distance between the two plates. So the amplitude and phase of the reflection coefficient is the function of the distance between the two plates.

The structure of 20H rule can be estimated by the power plane and the mirror plane in Figure 3. Because the distance between the power plane and the mirror plane is 2 times longer than the distance in Figure 2(a), the reflection coefficient in Figure 2(b) is small than in Figure 2(a). Therefore, more radiation is expected to come out of the edges of the board implemented with 20-H rule.

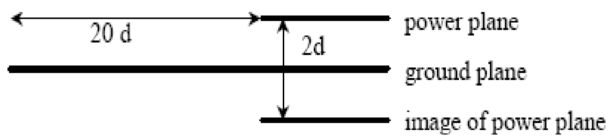

Figure 3: Image of the power plane in 20-H rule structure.

As we can understand that the model of this method is too simple and idealized; many practice factors have not been taken into account. So the conclusion is not scientific.

3.2. Finite Difference Time Domain Method (FDTD)

For researching 20H rule deeply, we can use more advanced method-Finite difference time domain method (FDTD) to analyze the radiations of applying 20H rule or not applying it. The focus is on the amplitude and distribution of the radiating field.

The following is how to build a model for analyzing and confirm the 20H rule by FDTD.

(1) The emulating model and excitation source of 2D plain structure.

For simplicity, we chose a 2D model to simulate the signal propagation between power plane and ground plane.

The PCB model has a power plane and a ground plane as shown in Figure 4. For simulating 20H rule, the following assumptions are made: 1. the power and ground planes have a good conductivity, satisfying the PEC condition; 2. both of two planes are infinitely thin in thickness; 3. the simulation is based on infinite space. In the following discussions, H stands for the distance between the layers of the PCB; E stands for electronic field.

As the power and ground planes satisfy the PEC condition (ideal conductivity), so two planes' tangential electric field should be zero. The blue mark in the figure stands for dipole excitation source.

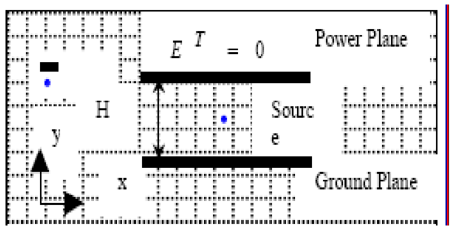

Figure 4: 2D planar structures.

As the limitation of the computer resources, we reduce the infinite space to a finite rectangular space. There is a appropriate matching layer fitted to the area edge. Taking the above condition into account, we build the simplest model.

They are three kinds of excitation sources which can be used in simulation. They are dipole excitation source, Uniform voltage excitation source and Gaussian pulse.

Here only introduce the dipole excitation source, usually in the center of structure, by enforcing the E field at this point, shown in the following equation:

$$E_{\text{center}} = E_0 \sin(2\pi f k dt) \tag{4}$$

where f = the frequency of the excitation source, k = time step number, dt = length of time step.

Different from the uniform voltage excitation source, the dipole source will not change with layers separation distance. This characteristic has an advantage in studying the 20H rule with different layer separation distance.

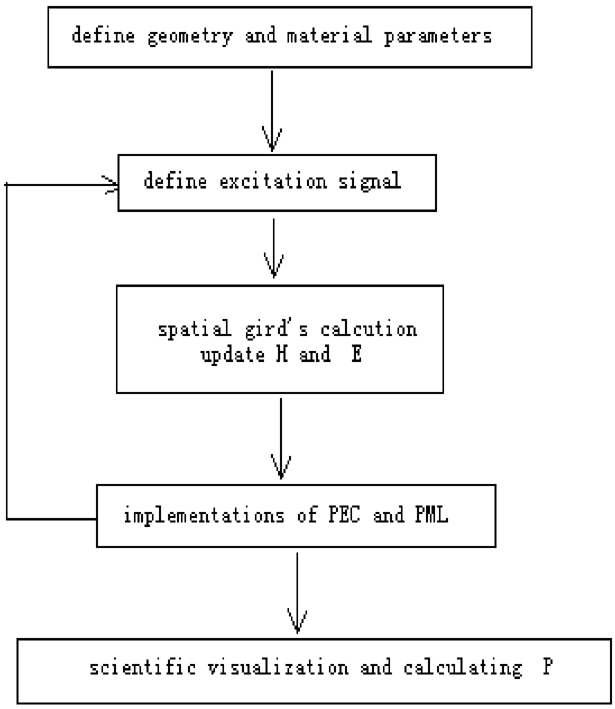

Figure 5: Flow chart of FDTD Method.

(2) FDTD Method

Figure 5 present a flow chart of FDTD algorithm. The first step of for the FDTD simulation of a microwave structure is to define geometry structure and material parameters. That is: the interface of the dielectric and the conduction interface are specified on the computational grid in the step. The second step is to establish excitation signal. When the excitation source is made sure, the FDTD method should update all the field components on the computational grid for each step. Using the discrete form of Maxwell equation, the renewed equation can be modified. As the time step length satisfy the stable condition, so it can be reduced to:

$$\Delta t = \frac{\Delta x}{2C_0} \tag{5}$$

As a good conduction layer on the interface of the dielectric, the tangent part of the electric field is set to zero. With perfectly matched layers (PML) is used as the absorbing boundary conditions, the tangent part of the field on the outer layers of the computational grids are updated.

(3) Energy Expression: *Poynting Vector*

For the study of the 20H rule effect, the PCB edge should be quantized. P represents the energy of the edge radiation. P vector stands for the density of electromagnetic energy which can be expressed as: $\overrightarrow{P} = \overrightarrow{E} \times \overrightarrow{H}(\overrightarrow{E}, \overrightarrow{H}$ stand for electric field and magnetic field intensity).

As the E and H are all instantaneous vectors, so P is instantaneous vector too. If we integrate P along a definite surface, it just results the energy out flown from a closed surface. This can also be applicable in 2D simulation. The only thing should be changed is along a line to integrate but not a closed surface, that is along the edge AB, BC, CD and DA as shown in Figure 6.

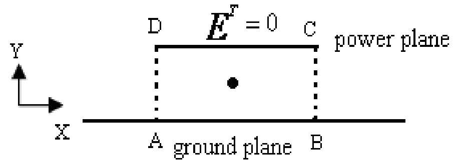

Figure 6: Integration route for the P.

The three components of the P:

$$P_x = E_y H_z - E_z H_y \tag{6}$$
$$P_y = E_z H_x - E_x H_z \tag{7}$$
$$P_z = E_x H_y - E_y H_z \tag{8}$$
$$\oint_{ABCD} P \cdot dl = -\int_{AB} P_y dl + \int_{BC} P_x dl + \int_{CD} P_y dl - \int_{DA} P_x dl \tag{9}$$

In time domain, for $\overrightarrow{P}$ vector, we can use different expression to represent different mode of the waves along this line (TE, or TM).

As the TE mode only has E_x, E_y and H_z along AB and CD, $E_x = 0$, so $P_y = 0$. Using Cartesian discretization, from expression 9 we can get:

$$\oint_{ABCD} \overrightarrow{P} \cdot dl = -\int_{DA} P_x dl + \int_{BC} P_x dl \tag{10}$$

For the same reason, TE mode only has E_z, H_x and H_y. Along AB and CD, we know $E_x = 0$, so $P_y = 0$. For TM mode, we can get the same result.

As the symmetric structure, the integral along the line can be simplified as:

$$\oint_{ABCD} P \cdot dl = 2\int_{BC} P_x dl \tag{11}$$

3.3. Practice Measuring Method

The theoretical analyze may differ from simulation. So we can use a real measure device to measure the edge radiation. The measure device is shown in Figure 7.

The results of measuring and simulation may also be not equal. This is because the real measure system is much complicated than simple model. On the other hand, the antenna, cable, measuring circumstances and the definition of the measuring devices and the near field effect all can be a factor affecting the measuring result. The radiation from the connector of excitation source may be greater than the edge radiation which make the measuring error larger than usual. All these factors can bring tremendous difficulties in the certification of 20H rules.

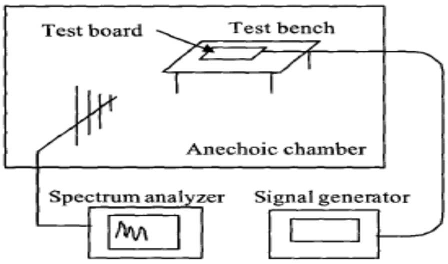

Figure 7: Measuring equipment.

4. CONCLUSIONS

As the above analyses are all based on bare PCB, unlike real PCB which has a lot dynamic digital components on, the real analyses can be very complex. Though we have not got the 20H rule's working mechanism, one thing is certain that he use of 20H rules resolved many EMC issues of PCB design.

Among the Confirming methods of 20H rule, the reflective coefficient is not a proper method for its limitation and incomprehensive. FDTD is an effective method. There are three major factors which will greatly affect the result when using FDTD. They are: operation frequency; the dimension and layer's separation of PCB. In addition, layer number, component's layout and layers setup would all be factors affecting the 20H rule's use. We need to build more precise model based on the above conclusion. Only more effective algorithm and program is promoted, can we analyze the 20H rule more efficiently.

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